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NECK LOADS IN FRONTAL IMPACT

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This paper is an analysis of the results of two cadaveric impact studies carried out at Wayne State University. In the first project, a series of 8 cadavers were restrained by a predeployed driver airbag and subjected to a severe frontal impact with a barrier equivalent velocity (BEV) of 50 km/hr. The second study involved 12 cadavers which were subjected to the same impact pulse but were restrained by a shoulder belt and a knee bolster, an automatic belt system. Details of the two studies can be found in Cheng et al (1) and (2). There were 3 'fatal' upper cervical injuries to the cadavers in the airbag runs and none in those restrained by the automatic belt. The injuries were non-survivable because they were either an atlanto-occipital separation or a C1-C2 separation. An example of this injury is shown in Figure 1. Neck loads were computed from head acceleration data in an attempt to find differences in injury mechanisms. It should be emphasized that this paper is a study of neck injury mechanisms and is not a comparison of the relative merits of the 2 automatic restraint systems.

Table 1 lists relevant data regarding test subjects and peak neck loads which were computed from head acceleration data, assuming full facial contact with the airbag for short subjects (less than 1.71 m tall), partial contact for taller subjects and no contact for belted subjects. A two-dimensional model developed by Mertz and Patrick (3) was used as a basis for this computation. It was modified to include a contact force of 2,600 N for full facial contact, since the bag pressure was 100 kPa and the facial area was about 0.026 m^2. The contact force for taller cadavers in the airbag series was assumed to be 1,300 N. The resultant force could peak out either at the time the shear force reached its peak or when the tensile force was at maximum. The first condition occurred when the subject was short and his head hit the airbag at a high velocity (early in the pulse). This impact resulted in a sudden increase in head deceleration and thus a large shear force at the base of the skull, as shown in Figure 2. For the taller subjects, head velocity was much lower at the time of airbag impact and the resultant force was generally lower. The resultant force peak for belted subjects was largely due to axial tension in the neck. The three cases of non-survivable neck injuries were all due to high shear forces in combination with high axial forces.

These results are in apparent contradiction to those of a 2-D neck model (King et al, 4) which predicted that neck loads were lower if there was head contact with the windshield than those due to a freely whipping head in a frontal crash. However, in this simulation, contact occurred late in the impact event and was somewhat similar to the case of the tall airbag subject. Thus, neck loads are not only dependent on head contact but also the severity of the impact. It is implied that head contact late in the impact event is less severe.

The conclusions are:

1. A resultant neck load of about 10 kN is required to cause a non-survivable high cervical injury.
2. Injury mechanisms of the neck are complex and multifaceted. More research is needed to understand fully the many ways in which the neck can be injured.
3. No conclusions can be drawn from these results regarding the relative efficacy of the airbag and the automatic belt system.

Figure 1. X-ray of airbag test with C1-C2 separation.

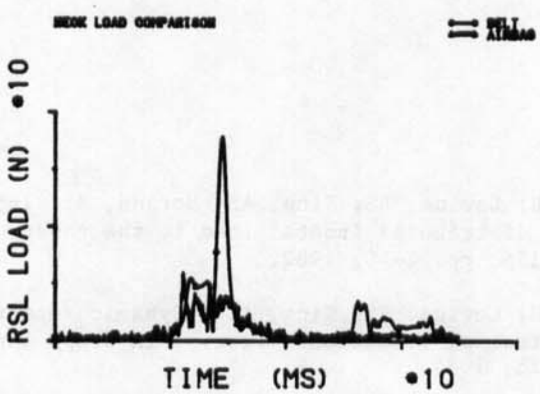

Figure 2. Comparison of typical neck loads - belted and airbag.

TABLE 1
RELEVANT CADAVERIC AND PEAK NECK LOAD DATA

RUN #	CAD #	SEX	AGE	HEIGHT (m)	WEIGHT (kg)	NECK LOADS AT MAX SHEAR (N) SHEAR	AXIAL	RESULTANT*	PEAK RESULTANT (N)	NECK INJ.
A1	5018	M	66	1.700	72.5	9000	6200	8911	8911	A/O Sep.
A2	5002	F	54	1.510	50.0	10800	6800	10653	10653	C1-C2 Sep.
A3	5074	M	56	1.850	96.0	2310	1875	2130	4860	
A4	5108	M	63	1.795	72.5	4700	2500	4220	5735	
A5	5316	M	68	1.755	83.0	12500	6688	13045	13045	C1-C2 Sep.
A6	5337	M	67	1.745	56.0	6900	3000	6353	6900	
A7	0064	M	61	1.685	87.5	1430	875	1461	3650	
A8	0076	M	60	1.880	85.7	3360	1875	2786	4300	
B1	0172	F	46	1.630	65.7	1550	1350	2055	2525	
B2	0164	M	60	1.752	79.3	1013	1275	1628	2081	
B3	0170	M	21	1.695	60.0	5250	4500	6915	6915	
B4	0194	M	65	1.670	56.2	1150	2800	3027	5120	
B5	0259	M	29	1.745	96.1	3896	470	3924	3924	
B6	0286	F	56	1.515	50.3	1964	2550	3219	3375	
B7	0312	M	50	1.790	90.7	1200	975	1546	3300	
B8	0362	M	63	1.730	69.0	5250	420	5267	8125	
B9	0371	M	58	1.620	78.5	7440	630	7467	7467	
B10	0375	M	58	1.735	73.0	3417	675	3483	3500	
B11	0385	M	63	1.765	51.0	5250	1125	5369	5369	
B12	0563	M	61	1.700	73.0		DATA NOT AVAILABLE			

A designates Airbag runs and B designates passive Belt runs.
*For Airbag runs, RESULTANT = $\sqrt{(\text{SHEAR-HEAD CONTACT FORCE})^2 + (\text{AXIAL})^2}$

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